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quency of nerve impulses discharged from the ganglion cells in voluntary contraction must lie between 300 and 5000 per second.

The complete paper will appear in the *American Journal of Physiology*, January, 1917.

## A PHYSIOLOGICAL STUDY OF NOCTILUCA, WITH SPECIAL REFERENCE TO LIGHT PRODUCTION, ANAESTHESIA AND SPECIFIC GRAVITY

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The specific gravity of *Noctiluca* is less than that of sea water, so that normally the animals float at the surface. They contain no air bubbles or large oil drops, and their lower specific gravity must therefore be due to a lower salt content than the sea water. In more concentrated sea water, the animals shrink and in more dilute sea water they swell; the plasma membrane therefore has the usual semipermeability toward the balanced salts of sea water, i.e., permeability to water and impermeability to salts. When placed in a mixture of 4 sea water; 6 fresh water, the animals sink, their salt content being now greater than that of the surrounding medium, but later they rise to the surface, a process independent of the movement of the tentacle. They must therefore have absorbed water not only until their salt content is the same as that of the surrounding medium (when they should still sink), but enough water to make their salt content again less than the 4 s.w.: 6 f.w. mixture, thus re-establishing their normal relation to the surrounding medium. This water must be absorbed against the osmotic pressure of the salts of sea water, a process contrary to physical laws. The animals can not only lessen their specific gravity, but they can also increase it, as is shown by the fact that on windy days they sink far beneath the surface of the sea. Anesthetics, acids and alkalis, KCN, and the pure solutions of the salts of sea water do not interfere with this regulatory mechanism except when they cause irreversible changes and death of the cells; dead *Noctiluca* always sinks to the bottom.

Light production in *Noctiluca* normally occurs only on stimulation of any kind, and is a momentary bright flash; dying animals produce a bright steady glow. The luminescence is traceable to points of light coming from granules in the protoplasm. No substances were found which would cause a rhythmic flashing, comparable to the rhythmic

twitching of a muscle in pure NaCl; the only responses given were the momentary bright flashing and the steady glow. The latter response was called forth by anesthetics, cold ( $5^{\circ}$ – $0^{\circ}\text{C.}$ ), heat ( $43^{\circ}$ – $49^{\circ}\text{C.}$ ), acids and alkalies, fresh water, and a constant galvanic or interrupted induced electrical current. Cells injured by puncturing with a needle or by passage of an induced current respond to mechanical or electrical stimulation by a flash just as normal cells do. If, however, the cells are completely broken to fragments by pressing them through cheese-cloth, they do not flash on stimulation although they do give a steady glow. Light production does not occur in absence of oxygen. The supposition that the cells are ordinarily impermeable to oxygen but become permeable on stimulation and on death, is not true, however, for the cells deprived of oxygen immediately give light when oxygen is readmitted. without being stimulated mechanically or in any other way.

Noctilucas may be anesthetized by certain concentrations of ether, chloroform, thymol, chloretone, ethyl and butyl alcohol so that they fail to give a flash on stimulation, but they always give a very faint glow; this disappears and the normal response returns on removing the anesthetic. *Noctilucas* differ in this respect from luminous bacteria whose light giving power can be completely anesthetized. (E. N. Harvey, *Biol. Bull.*, **29**, 1915, p. 308). Although the anesthesia of many processes, e.g., the contraction of heart muscle, cell division and growth has been shown to be independent of the consumption of oxygen, we should expect the anaesthesia of light production to be dependent on the consumption of oxygen since this process is a luminescent oxidation which will take place in solutions in a test tube free from cells. That this oxidation is different from that in most cells is shown by the fact that KCN has no effect on the light production in *Noctiluca* in relatively high concentrations, whereas it quickly paralyses the oxidations of most cells. The question arises whether the anesthesia of luminous cells is due to the fact that oxygen cannot pass through the membrane, or to the fact that it cannot be used. The latter alternative is suggested by the experiment of removing oxygen from the cells and readmitting it, thus showing that oxygen can pass the membrane at any time. The question is answered by an experiment in which the cell substance of anesthetized cells was permitted to come in contact with dissolved oxygen. Narcotized cells were broken up by shaking with sand, and it was found that they produced only a faint light whereas normal cells so treated became very brilliant. The anesthetic must therefore attack the mechanism of the utilization of oxygen in the cell, and not the permeability of the cell membrane for oxygen.